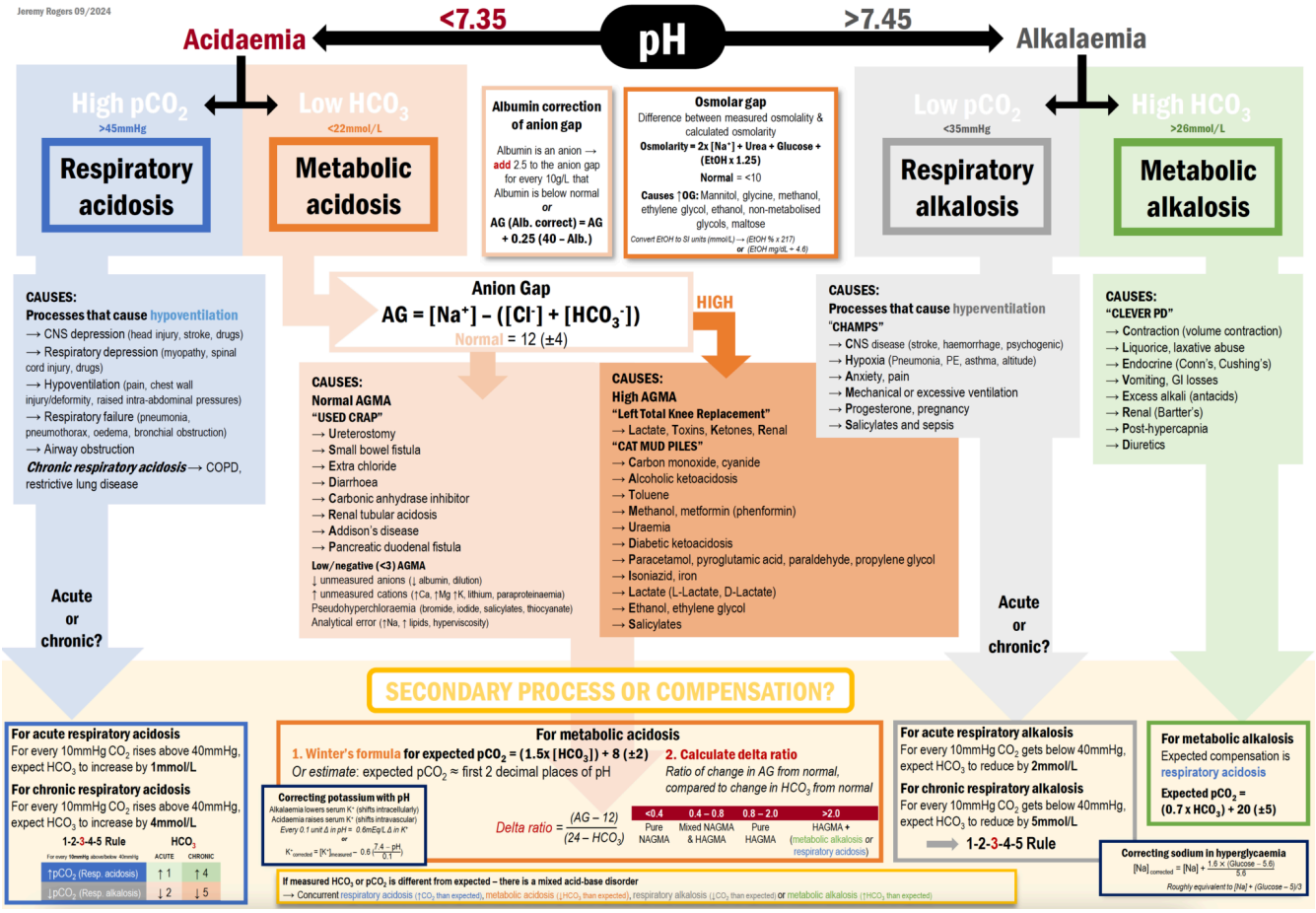
Blood Gas Interpretation

Jeremy Rogers and Mike Cadogan • Jun 26, 2026

The blood gas is used to rapidly assess ventilatory function and identify acid-base disorders – and will also generally provide point-of-care testing of a number of values such as electrolytes, blood glucose and haemoglobin.

Interpretation occurs in a systematic manner to identify the primary disorder, secondary disorders and therefore the differential diagnoses that could be contributing to the patient's clinical state.

Use the following steps and flowchart to approach blood gas interpretation in a comprehensive and structured manner:



Blood Gas Interpretation: Click on image for high resolution PNG or download the PDF

Interpreting the blood gas in a step-wise manner:

- Step 1. pH
- Step 2. Assess the pCO_2 and HCO_3 to identify the primary disorder
- Step 3. Consider the cause of the primary disorder
- Step 4. Assess for secondary processes
- Step 5. Apply corrections to certain measured values

Step 1. pH

A normal pH is between 7.35 and 7.45 (use 7.4 as the 'normal' value for all calculations)

- If pH < 7.35 there is acidaemia
- If pH > 7.45 there is alkalaemia

*If **pH is normal** – there could be no acid-base disorders occurring, or there could be multiple processes occurring concurrently*

> Remember – acidaemia/alkalaemia describe the pH status of the blood, not the process(es) driving the abnormality

Step 2. Assess the pCO_2 and HCO_3 to identify the primary disorder

- A normal pCO_2 is between 35 – 45mmHg (use 40mmHg as the 'normal' value for all calculations)
- A normal HCO_3 is between 22 – 26mmol/L (use 24mmol/L as the 'normal' value for all calculations)

If there is ***acidaemia***:

- An elevated pCO_2 indicates a respiratory acidosis
- A reduced HCO_3 indicates a metabolic acidosis

If there is ***alkalaemia***

- A reduced pCO_2 indicates a respiratory alkalosis
- An elevated HCO_3 indicates a metabolic alkalosis

Step 3. Consider the cause of the primary disorder

Respiratory acidosis (elevated pCO2) >

Metabolic acidosis (reduced HCO3) >

Respiratory alkalosis (reduced pCO2) >

Metabolic alkalosis (elevated HCO3) >

Step 4. Assess for secondary processes

If there is a primary metabolic disorder, there is an expected respiratory compensation that can be calculated, and vice versa for a primary respiratory disorder. Respiratory compensation occurs quickly (within 30 minutes and complete within 12-24 hours), whereas metabolic compensation begins within 5-10 minutes (with whole body buffering) but requires 3-5 days to complete with further renal processes.

If the degree of compensation is not appropriate (e.g. the expected pCO_2 or HCO_3 is above or below the measured value) this is indicative of concurrent additional acid base disorders occurring.

A respiratory acidosis is compensated for by increasing HCO_3

- Calculate the expected HCO_3 using **1-2-3-4-5 rule**

1-2-3-4-5 Rule	HCO_3	
For every **10mmHg** above/below 40mmHg	ACUTE	CHRONIC
↑pCO_2 (Resp. acidosis)	↑ 1	↑ 4
↓pCO_2 (Resp. alkalosis)	↓ 2	↓ 5

- This rule states that for ***acute respiratory acidosis*** the expected HCO_3 will increase by 1mmol/L (from the normal value of 24) for every 10mmHg that the pCO_2 rises above normal (40mmHg)
  - For ***chronic respiratory acidosis*** the expected HCO_3 will increase by 4mmol/L for every 10mmHg rise in pCO_2 above normal

A metabolic acidosis is compensated for by reducing pCO_2

- Calculate the expected pCO_2 using **Winter's formula**:

$$pCO_{2\ expected} = (1.5 \times [HCO_3^-]) + 8 \pm 2$$

- The expected pCO_2 can also be approximated using the two digits to the right of the decimal point (e.g. expected pCO_2 = 25 if the pH = 7.25)
  - If the measured pCO_2 is more than the expected pCO_2 – there is **also** a ***respiratory acidosis***

Delta ratio

In the context of a metabolic acidosis, a further calculation can be performed to assess whether the metabolic acidosis is due to single process or a mixed acid-base disorder. This is called the delta ratio, and reflects whether the change in the anion gap from normal (delta AG) is proportional to the expected change in the HCO_3 from normal (delta HCO_3).

$$\text{Delta ratio} = (AG - 12) / (24 - HCO_3^-)$$

If the denominator is larger (i.e. the HCO_3 has changed more than the change in anion gap) this could reflect that a NAGMA is present (either by itself or concurrently with a HAGMA). If the numerator is larger (i.e. the anion gap has changed more than the change in HCO_3) this could reflect that there is predominantly a HAGMA occurring – or if the ratio is very high (>2) this could reflect that there is an additional process present (such as a concurrent metabolic alkalosis or a chronic respiratory acidosis which is raising the HCO_3 and reducing the delta HCO_3)

Delta ratio interpretation:

<0.4	Pure NAGMA
0.4 – 0.8	Mixed NAGMA and HAGMA
0.8 – 2.0	Pure HAGMA
>2.0	HAGMA and either metabolic alkalosis or chronic respiratory acidosis

A respiratory alkalosis is compensated for by reducing HCO_3

- Calculate the expected HCO_3 using **1-2-3-4-5 rule**
- This rule states that for ***acute respiratory alkalosis*** the expected HCO_3 will reduce by 2mmol/L (from the normal value of 24) for every 10mmHg that the pCO_2 drops below normal (40mmHg)
  - For ***chronic respiratory alkalosis*** the expected HCO_3 will reduce by 5mmol/L for every 10mmHg reduction in pCO_2 below normal
- If the measured HCO_3 is **less than** the expected HCO_3 – there is also a **metabolic acidosis** occurring.
- If the measured HCO_3 is **greater** than expected – there is also a **metabolic alkalosis**.

A metabolic alkalosis is compensated for by increasing pCO_2

- Calculate the expected pCO_2 using:

$$pCO_{2\ expected} = (0.7 \times [HCO_3^-]) + 20 \pm 5$$

- If the measured pCO_2 is more than the expected pCO_2 – there is also a respiratory acidosis occurring
- If the measured pCO_2 is less than expected – there is a concurrent respiratory alkalosis.

Step 5. Apply corrections to certain measured values

In certain acid base disturbances, particular measured values may be falsely normal/abnormal and correction factors can be applied to assess for further abnormalities.

Albumin correction of anion gap

Albumin is an anion, therefore hypoalbuminaemia may under-estimate the anion gap. To correct the anion gap for hypoalbuminaemia – for every 10g/L that the albumin is below normal (40g/L) add 2.5 to the calculated anion gap

$$\text{Anion gap}_{\text{Albumin corrected}} = \text{Anion gap} + 0.25\ (40 - \text{Albumin})$$

Osmolar gap

The osmolar gap technically compares two different values – the osmolality (measured in the laboratory with freezing point depression, mOsm/kg), and the osmolarity (calculated, mOsm/L). Normally the gap between these two values is less than 10, and if the osmolar gap is elevated it can reflect the presence of an abnormal solute (e.g. toxic alcohol)

$$\text{Osmolarity} = (2\text{x}\ [Na^{+}]) + \text{urea} + \text{glucose} + (1.25\ \text{x EtOH})$$

Note: Ethanol must be converted to SI units (mmol/L)

$$\text{EtOH (mmol/L)} = \text{EtOH (\%)} \text{ x } 217 = \text{EtOH (mg/dL)} \div 4.6$$

Exogenous agents associated with an elevated osmolar gap

- Acetone
- Ethanol
- Ethylene glycol
- Glycerol
- Glycine
- Isopropyl alcohol
- Maltose
- Mannitol
- Methanol
- Propylene glycol

Other conditions (non-toxicological) associated with an elevated osmolar gap

- Alcoholic ketoacidosis
- Chronic renal failure
- Diabetic ketoacidosis
- Hyperlipidaemia
- Hyperproteinaemia
- Severe lactic acidosis
- Shock
- Trauma and burns

Sodium correction in hyperglycaemia

In patients with marked hyperglycaemia, the elevated serum glucose raises the serum tonicity (as the glucose cannot enter cells) which pulls water out of cells and expands the extracellular water compartment – thereby lowering the concentration of sodium.

The corrected serum sodium can be calculated, which represents what the serum sodium concentration would be if the glucose level was reduced back to normal. If the corrected sodium is in a normal range – the patient does not have a concurrent hypotonic hyponatraemia.

$$[Na]_{corrected} = [Na] + 1.5x([Glucose - 5.5]/5.5)$$

Roughly approximate to $[Na]_{corrected} = [Na] + (Glucose - 5)/3$

Potassium correction with pH abnormalities

Acid-base disturbances will affect the serum concentration of potassium – where *acidaemia* will **increase** the measured serum potassium by causing extracellular shift, and *alkalaemia* will **reduce** the measured serum potassium by causing intracellular shift.

The described relationship is that for every 0.1 unit change in pH, there will be a 0.6mEq/L change in serum potassium

$$K^{+}_{corrected} = [K^{+}]_{measured} - 0.6\ ([7.4 - pH] / 0.1)$$

Arterial Blood Gas Analysis

ABG Parameter			ABG result	Calculation and interpretation		
pH	>7.45	Alkalaemia		**pH**	**pCO2**	**Interpretation**
	7.36-44	Normal				
	<7.35	Acidaemia		↓	↓	Metabolic acidosis
pCO2	>45	High		↑	↑	Metabolic alkalosis
	35-45	Normal		↑	↓	Respiratory alkalosis
	<35	Low		↓	↑	Respiratory acidosis
HCO3	>26	High		**Corrected standard AG for albumin**		
	24+/- 2	Normal		$\frac{\text{Albumin}}{4} + 1.5 \times \text{Phosphate}$		
	<22	Low				
AG	> 16	High		**Anion Gap calculation**		
	12+/-4	Normal		$\{[Na+] - [Cl^- + HCO_3]\} = 12+/-4$		
	< 8	Low		**Corrected Na+ for AG in hyperglycemia**		
Glucose	>10	High		$\text{Corrected Na+} = \text{Na} + \frac{\text{Glucose} - 5}{3}$		
	< 2	Low				
Gap: Gap	$\frac{\Delta AG}{\Delta HCO_3} = \frac{AG - 12}{24 - HCO_3}$			**Gap: Gap calculation for metabolic acidosis**		
				<0.4	Low or Normal AG metabolic acidosis	
				0.4-0.8	Normal + high AG metabolic acidosis	
Lactate	**<1.9**	Normal		0.8-2.0	Pure high metabolic acidosis	
	>2.0	High		>2.0	Metabolic acidosis with metabolic alkalosis/respiratory acidosis	
pO2	80-100	Normal		**PAO2 = [713 x FiO2] – [pCO2 x 1.25]**		
	< 80	Hypoxia		**A-a gradient = PAO2 – PaO2 =** $\frac{\text{Age}}{4} + 4$		

Compensation rules for				
Expected PCO2	**Metabolic acidosis**		**Metabolic alkalosis**	
	1.5 X [HCO3] + 8 (+/- 2)		0.7 X [HCO3] + 20 (+/- 5)	
Expected HCO3	**Respiratory acidosis**		**Respiratory alkalosis**	
	Acute	Chronic	Acute	Chronic
	$24 + \frac{pCO2 - 40}{10} \times 1$	$24 + \frac{pCO2 - 40}{10} \times 4$	$24 - \frac{40 - pCO2}{10} \times 2$	$24 - \frac{40 - pCO2}{10} \times 5$

References and Links

Introduction to ICU Series

Critical Care

Compendium

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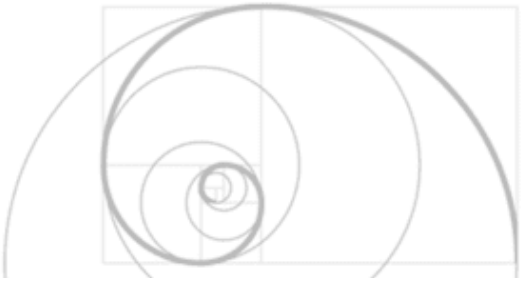

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6 Comments

Valerie R SEPTEMBER 25, 2020 / 08:26 REPLY

Thank you… very helpful

Rene Verbeek OCTOBER 18, 2020 / 01:45 REPLY

The aniongap is usually calculated without potassium en that value is used to calculate the delta ratio. What if the potassium is high? Is that a reason to include it, which will give a change in the delta-ratio compared to not using the potassium?
This question was raised when interpreting the following ABG:
pH 6.98; pCO2 14 mmHg (1.9 kPa); HCO3 3 mmol/l; Na 138 mmol/l; K 7.0 mmol/l; Cl 114 mmol/l

With kind regards,
René

Praful Zinzuwadia AUGUST 16, 2025 / 10:51 REPLY

very simple explanation to learn acid-base disorders

Blood Gases Made Easy – Medblobs NOVEMBER 12, 2025 / 14:08 REPLY

[…] https://litfl.com/acid-base-disorders/ […]

simon FEBRUARY 26, 2026 / 23:34 REPLY

super explanation, thank you so much

Evelyn Nyarkoh MAY 9, 2026 / 20:41 REPLY

Acid-base imbalance made less complex. Thank you so much.

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